Teaching Activity: What's So Special About CO_2?

Introduction:

When considering why only certain gases in the Earth's atmosphere absorb infrared radiation, it is necessary to understand the concept of *resonance frequency.* Both infrared and visible light are forms of energy that radiate through space, have wave properties and vibrate at certain frequencies. The only difference between them is that visible light photons vibrate from twice to ten times as fast as infrared light photons. When an infrared photon encounters a molecule of carbon dioxide, methane or other greenhouse gases, the speed of the vibration "resonates" with the structure of the molecule. The molecule absorbs the energy from the photon and the vibration can be measured as heat. Visible light photons vibrate too fast to resonate with the structure of greenhouse gas molecules, and so the photons pass right through without heating the gas. The natural frequency vibrations of molecules of nitrogen and oxygen, which make up most of our atmosphere, do not match those of either visible light or infrared radiation. Therefore, neither of these gases are able to absorb these types of energy and are "transparent" to both visible light and infrared energy, allowing them to pass through unimpeded.

Objective:

- To understand the concept of resonance frequency;
- To simulate the resonance frequency of certain molecules using models with different characteristics;

Important Terms: Visible light, infrared radiation, carbon dioxide, methane, greenhouse gases, photon, vibration, frequency, molecule, absorption;

Materials:

- 12 styrofoam balls, about 2-3 inches in diameters;
- 5 three foot lengths of thin, springy steel rods, 1/16 in. in diameter;
- 4 clocks or watches with a second hand;
- Pliers or wire cutters to cut the rods;
- Paper/pencil;

Preparation:

1. Before class:
    - Cut two of the rods into 1 foot lengths.
    - Color or label the balls to represent C, H or O.
    - Prepare copies of the molecule information card for distribution.

2. In class:
    - Divide the class into 4 teams.
    - Give each group the appropriate molecule information card (CO_2, CH_4, O_2, N_2) and each student a copy of the **Student Work Sheet**.
    - Each team will construct 1 model of a molecule. Go over **the Student Work Sheet** with the class.

- When all the models are completed. teams will exchange models so that each group can compare how the different molecules respond to different frequencies of vibration.

3. Instruct students to be sure that their **Data Table** and **Conclusions** are completed at the end of the activity.

Notes:

Sample Data Table:

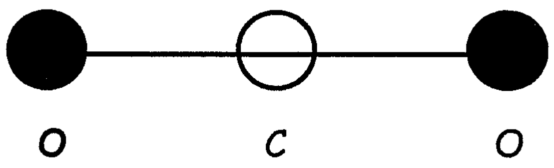
TRIAL #	No. Of Vibrations	Resonance Frequency
1		
2		
3		
4		
5		

Carbon dioxide (CO_2) Team

Materials: 3 styrofoam balls, 1 long (3 feet) steel rod, 1 clock or watch;

Procedure:
-Insert the metal rod through a ball representing a carbon atom. Adjust the ball so that it is centered on the rod.
- Add a ball to each end of the rod to represent oxygen.

Example:

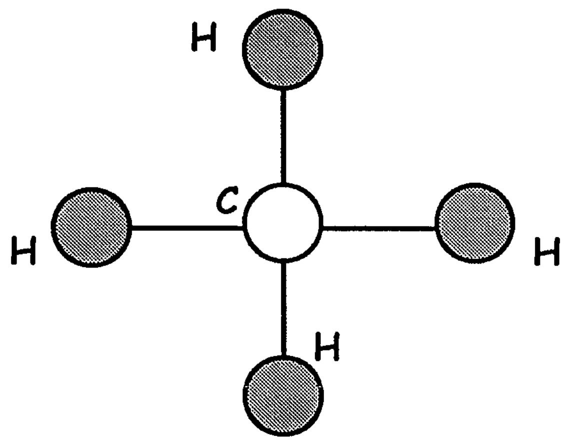


Methane (CH_4) Team

Materials: 5 styrofoam balls, 2, 3 feet long steel rods, 1 clock or watch;

Procedure:
- Insert 1, 3 feet long rod through a ball representing a carbon atom.
- Insert a second rod of the same length through the carbon atom at a right angle to the first rod. You should now have a carbon atom with 4 "spokes".
- Add 1 ball to the end of each spoke to represent hydrogen atoms.

Example:



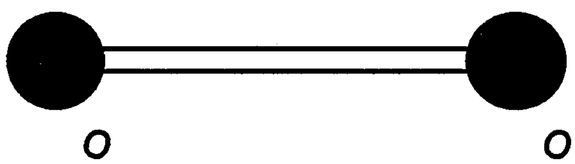
Oxygen (O_2) Team

Materials: 2 styrofoam balls, 2 short (1 foot) rods, 1 clock or watch;

Procedure: - Insert 2 short rods into one side of a ball representing an oxygen atom;

- Push the second ball onto the other ends of the rods so the two "atoms" are joined by the rods.

Example:



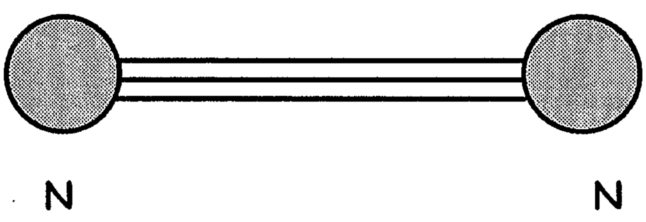
Nitrogen (N_2) Team

Materials: 2 styrofoam balls, 3 short (1 foot) rods, 1 clock or watch;

Procedure: - Insert 3 short rods into one side of a ball representing a nitrogen atom. Make the rods parallel.

- Push the second ball onto the other ends of the rod so the two "atoms" are joined by the rods.

Example:



Student Work Sheet

I. Procedure:

1. Construct the molecule assigned to your team, following the directions given to you by your teacher.

2. Start with the molecule constructed by your team:
   * If it is carbon dioxide or methane, hold it by the center atom and shake it.
   * If it is nitrogen or oxygen, hold it by either end and shake it.
   * Keep the shaking movement within a range of 6 inches.
   * Try a range of shaking speeds, or frequencies, from very slow (1 shake per second) to very fast (7-8 shakes per minute).
   * Use the clock / watch to time the shaking.

3. Try to find a frequency at which it is much easier to keep the model vibrating. This is the "resonance frequency" of the molecule.
   * Count the number of vibrations in a 5 second interval.
   * Write this information in the Data Table in the appropriate column.
   * Divide the number of vibrations by 5.

     Ex: No. Of vibrations x 5 = Resonance frequency.
   * Write this number in the appropriate column in the **Data Table.**

3. Do **at least 3 trials** until you are convinced that you have found the resonance frequency of your molecule.

4. Exchange models with other groups and try to determine the resonant frequency for each model.

5. Answer the questions in the **Conclusions** section on the next page.

Name ______________________ Date ________________

I. Data Table:

TRIAL #	Number of Vibrations	Resonance Frequency
1		
2		
3		
4		
5		

II. Conclusions:

1. Which of the four models had the fastest resonance frequency?

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2. If there are differences in resonance frequencies, why do you think they are different? ____

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3. The behavior of the molecules built from the styrofoam balls are useful analogies to the behavior of real molecules in the atmosphere. From the observations that you made of the models and the interaction with the different frequencies of vibration, why do you think that some of the gases in the atmosphere absorb infrared radiation and other do not?

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